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AN INVESTIGATION ON MECHANICAL BEHAVIOUR OF NYLON 6- POLYCARBONATE HYBRID COMPOSITE

R. SRIMURUGAN[1], B. VIJAYA RAMNATH[2] & C. ELANCHEZHIAN[3]

[1]*Assistant Professor, Department of Mechanical Engineering, M. N. M. Jain Engineering College, Chennai, Tamil Nadu, India*

[2]*Research Scholar, AMET Deemed to be University, East Coast Road, Kanathur, Tamil Nadu, India*

[3]*Professor, Department of Mechanical Engineering, Sri Sairam Engineering College, West Tambaram, Chennai, Tamil Nadu, India*

ABSTRACT

Nowadays, a composite material replaces conventional materials, in various applications like automotive, aerospace, marine and some electrical applications. In his work composites are fabricated by a compression moulding process by using Polycarbonate, Nylon 6 as reinforcement and epoxy resign as matrix. Here, Composite 1 contains 90% Nylon and 10% GFRP while Composite 2 contains 90% polycarbonate and 10% GFRP powders. Mechanical properties like, tensile, flexural, impact, and hardness are found, the result shows that composite 2 have better mechanical behaviour than composite 1 which make it suitable for various mechanical and electrical applications requires ballistics behaviours.

KEYWORDS: Polycarbonate, Nylon 6, Compression Moulding & Mechanical Properties

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Original Article

INTRODUCTION

Polymer composites ate playing vital role in automotive applications and mainly electrical applications. Here, work done by some researchers using Nylon-6 and Polycarbonate are discussed.

Reviews on Nylon 6 Composites

Zhiliang Huang et al (2017) investigated on the three types of straws that are mixed with nylon 6. The mechanical properties and crystallisation behaviour of the three straws/nylon 6 studied. After treating the wheat straw, maize straw and rice straw, using melt blending method they were mixed with nylon 6. The mixture was subjected to tensile test, impact test, differential scanning and X-ray diffraction, also their structure was studied using SEM analysis. From the results, the authors concluded that the tensile strength increased initially and then decreased. The impact strength decreased initially and then increased. In terms of crystallisation point of view, the increase in straw fibre produced increased grain size of the composite and the optimal straw fibre content was 10%. Junchun Yu et al (2011) investigated on the high-pressure crystallized MWCNT/nylon-6 composites. The microstructure, nucleation and thermal properties were deeply studied. The in-situ polymerized composites was studied using WAXD, DSC and NMR. From the result, the authors concluded that due to pressure while fabrication resulted in increased crystallinity to about 58%. This addition of MWCNT resulted in increased melting temperature of the composite and the thermal stability

found to higher to their grain growth. From NWR it is noted that there has been no covalent bonds found between nylon-6 and MWCNT. Florian Puch & Christian Hopmann (2014) investigated on the Nylon 6/multiwalled carbon nanotube-composites. The unreinforced and short carbon fibre reinforced was fabricated and studied their morphology and their tensile properties. From the study, it is concluded that during tensile tests, SCF reinforced fails due to fibre pull-out and MWCNT fails due to fracture. The morphology study shows that the two types of fibres were randomly oriented. Moreover, the young's modulus and tensile strength of SCF increased with increased amount of filler volume content. Lei Gong et al (2015) investigated on the nylon-6/graphene composites which were modified using graphene polymerisation. The graphene oxide with PVA linked by ester with nylon-6 was studied. The crystallisation was studied using the DSC and XRD studies. It has seen that the interface adhesion between the nanosheets and matrix were improved by GO-es-PVA composites, which was studied by SEM and TEM. Du Ning et al (2010) investigated on the nylon 6/graphite composites' preparation and characterization. The composite was fabricated using beta-caprolactam monomer polymerization blended with graphite oxide (GO). The tests that were conducted on the composite resulted that the IR spectrum confirmed the stretching vibration was due to amide group. The XRD showed the successful oxidation of NG as the diffraction peaks of GO shifted. Moreover, the increase in concentration of GO increased the electrical conductivities of the composite.

Jihui Li et al (2012) investigated on the nylon-6/flake graphite composites and its preparation. The main objective is to prepare them with antistatic property and thermal stability. Three types of nylon-6 composites with graphite derivatives (FG, GIC and EG) were prepared by insitu polymerisation. From the preparation, the authors concluded that as the mass percent's of FG, GIC and EG increases the volume resistivity decreases which is due to antistatic principle. Moreover, as the EG mass percent increases, the thermal stability found to be enhanced. Sinto Jacob et al (2010) investigated on the polypropylene–nylon fibre composite and its effects when nanosilicawas introduced as the reinforcing material. Here, two types of nanosilica were used, namely normal nanosilica and modified nanosilica (silanecoupling agent). The filler materials' compounding characteristics and its mechanical properties were studied. From the results, the authors concluded that at 1% nanosilica showed higher tensile strength and composites with 1wt%of modified nanosilic and 10%wt of nylon showed higher impact strength. Prashant Meshram et al (2018) investigated epoxy and nylon/epoxy composite and their mechanical properties. Here the composites were fabricated using hand lay-up technique. The nylon act as the reinforcing agent and epoxy as the matrix material. The fabricated material and the pure epoxy were compared based on the tensile strength and drilling thrust. From the results, the authors concluded that the composite with a nylon reinforced agent showed better tensile properties than the pure and there has been little variation in the obtained values in the thrust forces. Nan Feng et al (2013) investigated on the surface modification of recycled carbon fibre and its reinforcement effect on nylon 6 composites. The composites' mechanical, crystallisation and morphology were put under study. Recycled carbon fiber (RCF) acts as the reinforcement agent. From the study, authors concluded that the surface modified RCF showed better interfacial adhesion. Due to the same reason, the mechanical and thermal properties improved to a higher level. In addition, from the morphology studies from the fracture surface showed RCF had homogeneous dispersion in the nylon 6 composites. Moreover, nucleation density increased notably. Poonam Yadav et al (2015) investigated on the polycarbonate/multi-wall carbon nanotube nanocomposite. The composites' synthesis and dielectric characterization were studied. Using chemical vapour deposition and twin screw compounding extruder, MWCNTs and polycarbonate/MWCNT nanocomposites were prepared. Morphology was studied using SEM. From Raman analysis, the interaction between the MWCNT and polycarbonate were found to be good. From the dielectric impedance spectroscopy it

was found that the pristine polycarbonate had one dielectric relaxation, but the MWCNT loaded polycarbonate showed additional dielectric relaxation in the 10kHz region. Majid Tehrani Dehkordi et al (2013) investigated on the intraply basalt/nylon hybrid composites. The hybridization effect on the impact damage behaviour and compression strength were deeply studied. These were studied so as to combine the brittle nature of basalt and ductile nature of nylon fiber. With the different composition of nylon and different levels of impact energy were introduced to the composition. From the result, the authors concluded that with the increasing amount of impact energy, its performance depends on the content of nylon and basalt. Jelena Pavlicˇevic et al (2014) investigated on the influence of ZnO nanoparticles on polycarbonate-based polyurethane composites. Their thermal and mechanical behaviour was put under study. The ZnO influence was studied using Fourier transfer infrared spectroscopy and their thermal stability were studied using thermal gravimetry and DSC. From the results, the authors concluded that the addition of ZnO disrupted the phase separation, hence the thermal and mechanical behaviour gets affected in the polycarbonate-based polyurethane composites.

Reviews on Polycarbonate Composites

Yiqiang Zhao & David A. Schiraldi (2005) investigated on the polyhedral oligomeric silsesquioxane (POSS) /polycarbonate composites. This study throws light on the thermal and mechanical properties of the same composites. Here, the composite was prepared using melt blending method. Trisilanolphenyl 1 was found to be a better compatible material than the other POSS materials. It was found that the addition of trisilanolphenyl 1 enhanced the tensile and dynamic behaviour at the expense of decreasing ductility of nanocomposites. The same was felt when studied for thermal stability, which was due to the higher compatibility between POSS and polycarbonate.

Junchun Yu et al (2011) investigated on the MWCNT/nylon-6 composites. Here, the composites were prepared using insitu polymerisation and high pressure-high temperature treatment. With the addition of MWCNT, the glass transition temperature was increased. The thermal conductivity of the composites was improved by 27%. Moreover, the interfacial thermal resistance decreases and the crystallinity of the nylon-6 improved to 58% and improved crystal size. Ignazio Blanco et al (2018) investigated on the polyetherimide/polycarbonate blends and their thermal properties was studied for advanced applications. The prepared material was characterised based on their analysis using Thermogravimetric (TG) and Differential Thermogravimetric (DTG) analysis and Differential Scanning Calorimetry (DSC). From the analysis, the authors concluded that compared with pristine polymers the prepared composites showed formation of immiscible blend and with some partial miscibility. The presence of PC lowered the viscosity, which leads to improved processability. This composite finds its application in fusion deposition modelling 3D printing machine.

Gedler et al (2012) investigated on the thermal stability of polycarbonate-graphene nanocomposite foams. The foam composites were prepared using CO_2 dissolution one-step batch foaming process. The thermo gravimetric study of nitrogen and air atmosphere were studied for graphene induced solid and foam composites. From the results, the authors concluded that the one-step decomposition was found in N_2 atmosphere and three-step degradation in the air. In addition, the thermal stability remarkably increased for the foamed composites. Sumit Sharma et al (2015) investigated on the dynamic approach of MWCNT reinforced polycarbonate composites and their thermal cum mechanical characterisation were studied. The material was designed using material studio software and their corresponding mechanical properties were found using Forcite module of the same software. From the results, the authors concluded that due larger surface area and MWCNT's interaction with the base matrix there improved the mechanical properties of the composites. With the addition of 0.2% of MWCNT increased the overall elastic modulus by 10%. Drozdov et al (2003)

investigated on the polycarbonate reinforced

With short glass, fibres and their corresponding viscoelastic and viscoplastic behaviour were studied. The short glass fibres were studied at tensile tests in constant strain rate and oscillatory torsion tests at room temperature from which constitutive equations were developed. It has been found that the viscoelastic behaviour was due to the rearrangement of MRs and the viscoplastic behaviour was due to the breaking of linkages between MRs and meso-regions. Sudhir Kumar & K. Panneerselvam investigated on the nylon-6 and the glass fibre reinforced nylon-6 composite. Here the two-body abrasive wear behaviour of the composites were studied. The composites were fabricated using an injection moulding machine. The abrasive tests were carried out at different loads and different constituents of GFR in dry condition using 320 grit size abrasive paper. From the results, the authors concluded that the abrasive weight loss increases with increase in load and the as the GFR content increases the specific wear rate decreases. The worn surface was studied using SEM and Optical microscope.

Xiang Gao et al (2016) investigated on the ultrasonic treatment of polycarbonate/MWCNT composites. A twin-screw extruder technique was employed for the preparation of the composite. Here, processing characteristics, rheological, electrical, morphological and mechanical properties was studied. From the results, the authors concluded that the electrical and rheological percolation threshold decreased with ultrasonic treatment. However, there has been an improvement in the mechanical properties like young's modulus and elongation after ultrasonic treatment.

Binbin Yang et al (2017) investigated on the carbon fabric/polycarbonate composites and their uniaxial tensile and impact behaviour on different tow widths. Here, three different CF tow width weaves were prepared. From the experimental results, the authors concluded that the 20mm wide tow performed better than the other 8mm and 14mm tow, which showed better properties in the tensile strength, shear strength, peak force and enhanced impregnation. Cristobal Garcia et al (2017) investigated on the vibratory behaviour of glass fibre reinforced polymer interleaved with nylon nanofibers. The composites were numerically considered using a finite element model. The analysis was carried out using ANSYS workbench where the natural frequencies, damping and stiffness were found. From the analysis, the authors found that there has been a consistent increase in damping ratio and inter-laminar strength, but the variation in natural frequencies and stiffness were found to very small. This study shows that the simple FE model can predict the dynamic behaviour of the nanocomposites.

MATERIAL AND METHODS

In this work Nylon 6, Polycarbonate and GFRP in powder form are used to fabricate the composite laminates using compression melding process. Epoxy resin LY556 and Hardener HY951 are used to mix and prepare the samples in compression melding process. Here two types of composite namely composite 1 which contains 90% Nylon 6 - 10 % GFRP powder and composite 2 which contains 90% Polycarbonate - 10 % GFRP powder are fabricated. In each type, 3 samples are fabricated.

Testing of Composites

In order to study the mechanical properties of fabricated composites the following test were conducted as per ASTM standards. Table 1 shows the name of the test performed their ASTM standard and propose of the test.

Table 1: Name of the Test and ASTM Standard

Test No.	Name of the Test	ASTM Standard	Purpose of the Test
1	Tensile	ASTM D:638	To find the tensile behaviour like maximum tensile strength, percentage elongation and tensile modulus
2	Flexural	ASTM D :790	To find the three point bending behaviour like maximum flexural load and flexural modulus
3	Hardness- Shore-D	ASTM D ;2240	To know hardness of materials that resist indentation
4	Impact -Izod	ASTM D: 4812	To know amount of energy absorbed by the material while applying impact load on it.

RESULT AND DISCUSSIONS

The results of the tested composites are furnished in the following table.

Result of Tensile Test

From table 2 it is observed that composite 1 has a maximum tensile strength of 66.66 MPa while composite 2 has 80 MPa. This is due to the presence of polycarbonate in composite 2 which take maximum tensile load by undergoing maximum deformation. Since, the tensile properties of polycarbonate are higher than nylon 6, composite 2 shows better mechanical behaviour than composite 1. Figure 1shows Result of tensile test.

Table 2: Result of Tensile and Flexural Test

Combination of Materials	Name of Composites	Tensile Strength	Flexural Strength
Nylon6 + GFRP	Composite 1	66.66 Mpa	76 Mpa
Poly carbonate + GFRP	Composite 2	80.07 Mpa	161.87Mpa

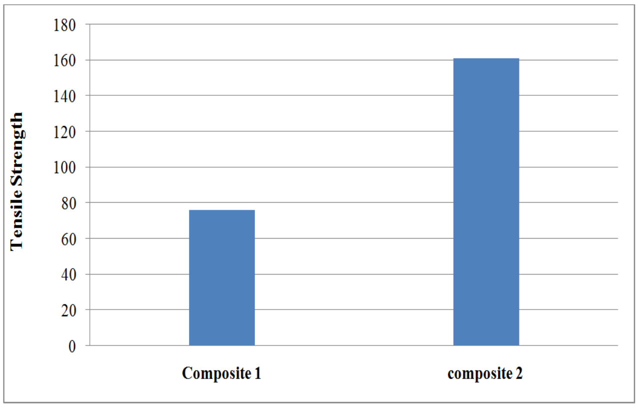

Figure 1: Result of Tensile Test

Result of Flexural Test

Result of three point bending test shows that composite 2 has 2 times the flexural strength of composites1. This is also the due to the presence of polycarbonate which has flexural strength between 95-105 MPa. This leads to the increasing the bending characteristic of composite 2 as compared to composite 1 which contains nylon 6. The inferior flexural properties of Nylon 6 make it to break/tear immediately while applying bending load as compared to polycarbonate based composites. Figure 2 shows the result of flexural test.

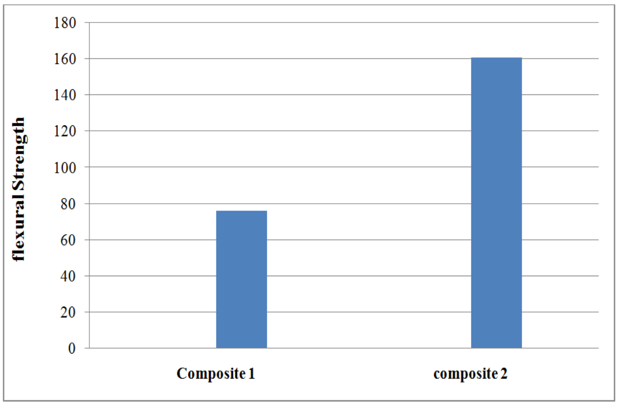

Figure 2: Result of Flexural Test

Result of Hardness and Impact Test

Table 3 shows the results of hardness and impact test.

Table 3: Result of Hardness and Impact Test

Combination of Materials	Name of Composites	Hardness Value- Shore-D	Impact Strength (J/mm)
Nylon6 + GFRP	Composite 1	82.33	2.54
Poly carbonate + GFRP	Composite 2	87	66

In this work, hardness test was conducted with Shore D value which is furnished in table 4. From the result, it is observed that, hardness of both composite 1 and 2 is nearer to each other like 82 and 87 respectively. The Izod impact test was conducted to know the energy absorbed by both composites. It is noticed that composite 2 absorbs 66 J/mm which is very much higher than composite 1. It is mainly due to the presence of polycarbonate which has high tensile behaviour. Due to this high value, this composite 2 can be recommended for electrical insulation application where high impact load situation can be arises.

CONCLUSIONS

In this work polymer matrix composite was fabricated using a compression moulding process with Nylon 6 and Polycarbonate as reinforcement namely composite 1 and 2 respectively. In I found that composite 2 has better tensile and flexural behaviour as 80MPa and 161 MPa respectively. Also, it was noted that composite 2 has a hardness of 87 with D shore scale and absorbed 66J/mm as a result of impact test.

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